ISSUE PAPER

BY THE

SCIENTIFIC AND ENGINEERING ADVISORY PANEL ON POPLAR RIVER AIR QUALITY

Edited by

James W. Gelhaus
and
Michael D. Roach

AIR QUALITY BUREAU

ENVIRONMENTAL SCIENCES DIVISION
MONTANA DEPARTMENT OF HEALTH AND ENVIRONMENTAL SCIENCES
HELENA, MONTANA 59601

March, 1979

SCIENTIFIC AND ENGINEERING ADVISORY PANEL

VEGETATION:

Clint Carlson, Forestry Department, University of Montana, Missoula, Montana
Dr. Clancy Gordon, University of Montana, Missoula, Montana
Dr. Wayne Williams, Consultant/Plant Pathologist, California, Chairman
Phil Tourangeau, University of Montana, Missoula, Montana

HEALTH EFFECTS:

Dr. Kit Johnson, Pediatrician, Missoula, Montana
Dr. Martin Skinner, Epidemiologist, Department of Health & Environmental Sciences, Chairman
Dr. John Anderson, Department of Health & Environmental Sciences

ATMOSPHERIC DIFFUSION AND MODELING:

Dr. Jim Heimbach, Montana State University, Bozeman, Montana, Chairman
Gerald Mueller, Lt. Governor's Office, Helena
Jim Gelhaus, Meteorologist, Air Quality Bureau, Department of Health & Environmental Sciences

POWER PLANT AND CONTROL AND ENGINEERING:

Dr. Carlton Grimm, Chemical Engineer, Montana Power Company, Butte, Montana
Dr. Ron Erickson, Chemist, University of Montana, Missoula, Montana Chairman
Charles Green, Montana Energy Research and Development Institute, Butte, Montana
Gordon Huddleston, Montana Energy Research and Development Institute, Butte, Montana

VISIBILITY:

Mike Ruby, Air Resources, University of Washington, Seattle, Washington; Chairman
Clint Carlson, Forestry Department, University of Montana, Missoula, Montana
Jim Gelhaus, Air Quality Bureau, Department of Health and Environmental Sciences

ISSUE PAPER

by the

SCIENTIFIC AND ENGINEERING ADVISORY PANEL
ON POPLAR RIVER AIR QUALITY

In July, 1978, the Montana Department of Health and Environmental Sciences requested the formation of a technical panel to review the issue relating to air quality of the Poplar River area. The review was requested due to the apparent lack of sufficient analyses of the effects of the proposed Canadian power plants being built near Coronach, Saskatchewan. Formation of the panel brought together Montana scientists and engineers who recognized the air quality problems that could result from construction and operation of facilities such as the Poplar River power plants.

The basic goals of the panel were:

(1) to summarize the work done to date;

(2) to point out the unanswered questions;

(3) determine the predicted effects of the power plants based on data or experience, and;

(4) recommend how the effects of the plants should be minimized and measured.

I. INTRODUCTION

Montana first became involved in the discussion with Saskatchewan over the Poplar River project in early 1975. Governor Judge wrote the U. S. Department of State in January, 1975, citing potential effects on the quality of air and water, and formally requested the involvement of the International Joint Commission (IJC). The IJC is a panel of Canadians and Americans which attempts to settle trans-boundary disputes between the U. S. and Canada. Following the Governor's letter, there were several meetings and considerable correspondence regarding water quality and water use by the proposed plants. The first air quality discussions were in February, 1975. The IJC announced then that the International Air Pollution Advisory Board (IAPAB) was to review the Canadian project for potential air quality impacts as soon as possible. In April, 1975, the IAPAB received the first detailed information about the power plant. The design was for 96 percent particulate control but no sulfur dioxide control. Various meetings were held between the Saskatchewan government and EPA during the following months. In August, 1975, the Air Quality Bureau of the Department of Health and Environmental Sciences actively entered the air quality assessment. Work performed by the Canadians was reviewed and independent modeling was also performed. This modeling indicated that the Class II 24-hour Prevention of Significant Deterioriation

(PSD) sulfur dioxide increment would be exceeded as far as 19 km into Montana. This was for a 1200 Mw facility which was being discussed at that time. However, only the 300 Mw unit was committed to initially. Looking just at the 300 Mw facility, the PSD increment was not excpected to be exceeded. However, concern was expressed about the large area of Montana that would experience elevated sulfur dioxide concentrations. At this point, the Saskatchewan Power Corporation (SPD) said it could achieve 40 percent sulfur dioxide control by using the alkaline fly ash as a control medium during combustion. Particulate concentrations resulting from a 1200 Mw facility were predicted to exceed the PSD increments. Questions based on other power plant operations were raised about the validity of the emission rates of the particulates predicted for the Coronach plant. Various other questions were raised regarding the coal analyses and the meteorological data being used by both sides. The Canadians apparently did not consider whether the proposed plants would violate U. S. or Montana air quality regulations.

The corporation building the plant is the Saskatchewan Power Corporation (SPC). This is a Crown corporation totally owned by the Canadian government with condemnation rights over all the land needed for the power plant and strip mine. The two environmental agencies involved in Canada are the Air Pollution Control of the Department of the Environment, and the Air Pollution Control of the Environment Canada. These two are similar to the Montana Department of Health and the Environmental Protection Agency. Also involved in negotiations have been the Canadian External Affairs and the U. S. Department of State.

On August 21, 1975, the International Air Pollution Advisory Board reported to the IJC that a significant portion of Montana's air quality increments for particulate matter will be used up by the 300 Mw unit if better controls were not used. Considerable deterioration of the air quality would result if the unit was not equipped with an electrostatic precipitator (ESP) capable of 99+ control. A similar report was given concerning SO_2. If the 1200 Mw plant were built, it would cause much more deterioration of the air quality. Recommendation was made by the Advisory Board to have the unit constructed and operated with controls to limit the emission of particulates, SO_2 and NO_2 to the degree necessary to protect the public health standards in Montana.

On August 26, 1975, all the participants of previous Poplar River negotiations met in Helena. SPC at that time agreed to install electrostatic precipitators capable of 99 percent particulate control. The U. S. negotiating team stated that the best available controls required on U. S. plants was not being installed on the Coronach plant for either SO_2 or particulates. The negotiators agreed that there would be no violations of the standards for SO_2 in Montana for the 300 Mw unit if the Canadian emission figures were correct (40 percent SO_2 control by ash). The Air Quality Bureau requested coal samples for analysis at the August meeting.

On October 6, 1975, the same participants met in Ottawa to discuss the 300 Mw and 600 Mw units. The Air Quality Bureau was not represented. Those present concluded that the first 300 Mw unit would create no problems with sulfur dioxide, particulates, nitrogen dioxide, or fluoride in Montana. Canada wanted to discuss the 600 Mw size

at that time but the U. S. would not agree to this because the effects of the 300 Mw plant were not fully known. Discussion of SO_2 control on the first unit was dropped even though the Air Quality Bureau felt significant degradation of the air quality would occur. Canada also announced plans for a test burn of the Poplar River coal in a similar power plant.

On December 19, 1975, the test burn was conducted at the Canadian Boundary Dam Unit #1 power plant. EPA observed the tests.

On January 8, 1976, the Air Quality Bureau published the results of the coal analyses. Sulfur values varied from 0.64 to 1.09 percent on an as received basis.

EPA on January 26, 1976, expressed concern about the validity of the Canadian test burn of the coal because of poor sampling and analytical procedures. Poorly heated and uninsulated sample lines were the chief concern.

On April 19, 1976, the U. S. State Department said there was no apparent need for controls beyond those already agreed upon for air pollution emissions from the first unit. Emissions would be monitored from the first unit. If they were greater than those predicted or if increased transboundary air pollution occurred further negotiations wuld result.

In May, 1976, the results of the test burn were received by EPA. EPA evaluated the results and concluded that the accuracy of the results were for fluoride $\pm$ 20 percent and for SO_2 and NO_2 $\pm$ 75 percent. The results also showed a 36 percent sulfur retention by the fly ash. EPA formally requested further data on the test burn about one month later. Questions on the test burn were finally fully answered in

May, 1977. Additional coal analyses were also provided at that time.

In September, 1976, EPA and Montana state agencies presented a public meeting in Scobey to discuss the impacts of the plants and the proposed background studies.

In June, 1977, the Canadians advised the U. S. that they will be installing an ESP with 99.5 percent control. This was basically due to the fact that no 99 percent ESP's were available. Shortly thereafter, EPA's review of the test burn data showed 8.4 percent S retention. This analysis was reported to the Canadians on July 13, 1977, and at the same time additional coal and overburden samples were requested. Following several additional attempts to get the samples, the Canadians finally sent them to EPA in April, 1978. The Canadian analyses of the test burn indicated a capture of 21-24 percent of the sulfur.

At the latest meeting in Regina, EPA said the air quality case for negotiations is very weak due to the lack of specific data on effects. Lt. Governor Schwinden noted at that same meeting that he is worried about the long-range impacts on air quality.

In July, 1978, the Department of Health and Environmental Sciences brought together a variety of scientists, physicians, and engineers to examine the issue of the Poplar River power plants. The panel was divided into committees to address specific areas of concern. Each committee was asked to write briefly about the air quality relating to the power plants. The reports from the committees are consolidated in this document.

II. POWER PLANT CONTROL AND ENGINEERING

The power station and associated facilities are located southeast of the town of Coronach, Saskatchewan, and about four miles north of the international boundary. Near the construction site, the East Poplar River has been dammed to create a cooling reservoir, which, when full, will be 50 feet deep and cover 1605 acres. Pipes have been installed to supply cooling water to the turbines. These pipes have been designed to be large enough to handle a 1200 Mw facility. The construction of the dam and filling of the reservoir is essentially complete. Seeding of the dam surfaces is in progress. The reservoir is approximately four feet less than full. It is anticipated that spring runoff in 1979 will complete the filling.

The ash disposal pond has not yet been located. Drilling is in progress to find a satisfactory site. There are no known plans to line the pond to prevent possible loss of ash pond liquids into the water table. Whether it is necessary to line the ponds will be determined when the site is selected. There are no plans for how the ponds should be secured when they are eventually abandoned.

The mining area is located generally west of Coronach. The initial five-year mining plan will concentrate on sections 4, 5, and 6 of township 2, range 27. The overburden will be stripped with a 90 cubic yard dragline.

SPC says this dragline is large enough to strip overburden from enough coal to run a 600 Mw plant except possibly in areas where the overburden is thicker than normal. Normal overburden in this area is 85 feet over a coal layer about 10 feet thick. There are approximately 400 million tons of recoverable lignite coal in the Poplar River area. No plans are being made to temporarily vegetate the topsoil storage to lessen fugitive dust. Strip mining will be done by typical box cuts. About 160 acres of land will be mined each year to supply the first 300 Mw unit, and another 160 for the second 300 Mw unit. Reclamation methods are being discussed with the local residents as to contours and revegetation. No specific plans have been released.

The coal will be carried to the power plant by two seven-car unit trains, each of which will make a round trip every hour. The embankment for the coal supply railroad is complete except for the area directly next to the coal storage piles. The loading area is approximately 5-6 miles north of the border.

The power plant being constructed is now 600 Mw facility. A four hundred foot stack will serve the plant. The stack is capable of serving only the 600 Mw. An electrostatic precipitator will be installed capable of 99.5% particulate control.

The ESP manufacturer is American Air Filter. The exhaust gas volume is projected to be 568.2 cubic meters per second. The ESP plate area is 79.1 meters ^{2}/meters^{3}/sec. The ESP will be a cold precipitator at approximately 150 degrees C.

The boiler is a Babcock and Wilson pulverized coal-fired radiant heat boiler producing heat at the rate of 1,950,000 lbs/hour at 1,900 psi

and at a temperature of 1005°F. Coal consumption is estimated at 495,000 lbs/hour per 300 Mw based on an average BTU value of the coal of 5800 BTU/lb (3000 million BTU/hr heat input). The turbine-generator set is being installed and supplied by Hitachi Ltd., a Japanese firm.

The basic concern about the power plant control and engineering is the amount of sulfur dioxide and particulate matter that will be emitted. The amount of SO_2 emitted depends primarily on the sulfur content of the coal and the power plant design. The various coal analyses performed have been questioned on the basis that the sulfur content of the samples was not known to represent the sulfur content of all the coal to be used.

The coal test burns also raised questions. The coal was different in the two test burns. As Table I indicates, the coal samples were considerably different.

TABLE I

COMPARATIVE ANALYSES ON TEST BURN COAL

	Test Burn Coals*		Montana Analysis	
	Burn #1	Burn #2	%	(range)
Ash	22.32	12.2	15.95	(12.1 - 20.2)
Sulfur	1.31	1.25	0.9	(0.7 - 1.2)
Calcium	2.35	1.85	1.61	(1.3 - 2.0)
Sodium	0.40	0.304	0.184	(0.90 - 0.31)
Silica	4.0	1.84	3.34	(1.7 - 5.6)

*All analyses recalculated on a dry weight basis.

Note that the coals used in the two tests were very different. The material used in test burn #1 was, in fact, higher in ash, S, Ca, and Na than any sample analyzed in Montana. Clearly the high ash content of the coal used in test #1 (with its corresponding high content of Ca and

Na) should have led to some increase in sulfur capture relative to test #2.

Based on the analyses of the test burns, Table II indicates the percentage of sulfur that would be captured with the two types of coal.

TABLE II

SULFUR CAPTURE BASED ON TEST BURNS

Test	Canadian	EPA
#1	36%	8.4%
#2	21 - 24%	---*

*EPA did not fully analyze the second test burn.

The boiler types, configurations and operations varied enough in the two tests that the results are not comparable. In particular, in test #1 operational difficulties were reported with the boiler. Question was raised whether the amount of slag generated influenced the amount of sulfur removed. The second test burns were performed under highly controlled pilot plant conditions, which may have resulted in better than average sulfur removal.

The variety of problems associated with coal sampling and test burns makes the determination of the amount of sulfur retention by the ash very speculative. The Canadian officials in their latest assessment of the plant have used a 0% retention figure. The panel believes that the assessment should look at varying degrees of control such as 10%, 20%, and 30% and assess what the effect would be on the air quality. Also, it is believed that a range of sulfur contents should be assessed.

III. ASSESSMENT OF THE AIR QUALITY IMPACT

In 1976 the U.S. Congress appropriated special funds for the assessment of possible environmental impacts from the Poplar River power plants. The funds, although allocated year-by-year, are intended to allow the study to continue for five years. The first year of the study was 1977. Six air quality studies were funded initially. These included air quality monitoring, evaluation of upper air meteorology, visibility and vegetation chemistry and chemical analysis of coal and soil.

Prior to receiving the Poplar River funds, the Air Quality Bureau had been operating one particulate monitor at the Scobey Border Station. Upon receiving the funds, the Bureau expanded the monitoring to include three particulate monitors and one sulfur dioxide and nitrogen dioxide bubbler. These three stations have now been operating for about two years. The results of the monitoring in 1977 are as follows:

TABLE I

1977 - AIR QUALITY DATA FROM THE POPLAR RIVER AREA

Station	TSP Max. 24-hour	TSP Annual Aver.	SO_2 Max. 24-hour	NO_2 Max. 24-hour
1	107	21	ND*	.005
2	100	21	---	----
3	109	25	---	----
	(ug/m^3)		(ppm)	

*ND - none detected.

Precipitation was low in Scobey early in 1977, but the year ended with a near normal precipitation total. The recorded monthly levels of total suspended particulate correspond fairly well with the precipitation pattern. No Canadian data were available for analysis. Canada runs four particulate samplers in the power plant area, but these were criticized in the first year analysis because they were too close to the ground and poorly oriented to record TSP levels accurately.

Meteorology of surface and upper air is being measured as part of the Poplar River study. At the lower levels, wind, temperature, relative humidity, and solar radiation are being measured. Upper level measurements include the use of pilot balloons to determine wind speed and direction and the measurement of upper air temperatures. The temperatures are measured with small, balloon-borne radio thermometers called temperature sondes, which transmit the temperatures as the balloon rises to various altitudes. The current visibility in the area is also being assessed. Methods used to assess the visibility include Volz photometers and a combination of pyrheliometers and pyranometers. The visibility monitoring system is also being expanded to include a nephelometer.

The 1977 appropriation also required the sampling and analysis of vegetation in the Scobey area. Fourteen sites were marked and sampled for wheat, alfalfa, and native grasses. The vegetation was analyzed for trace elements in the Health Department laboratory. The sampling program was far from a complete vegetation study of the area and was performed only to establish current (background) levels of the various trace elements.

Soil samples from two vegetation sampling sites were prepared and stored at two locations - the Montana State University soil bank and the Air Quality Bureau laboratory in Helena. The soil samples were not analyzed.

If vegetation around the generating facilities begins to show pollution effects, the soil samples collected prior to plant startup could be compared to soils collected later to determine if pollution was affecting soil.

The final study required by the 1977 appropriation was an analysis of a series of coal samples from the Poplar River coal field. The samples provided by the Canadians came from one area of the field, disallowing any determination of average coal characteristics from the whole field. A second, more representative series of samples was obtained and has not been analyzed.

Provision has been made under the 1978 appropriation to expand the air quality monitoring to include a special (dichotomous) sampler which can measure concentrations of both respirable and non-respirable particulates at a given site. One additional wind speed and direction station also is being installed.

The potential pollution effects on vegetation have been evaluated by the EPA laboratory in Corvallis, Oregon, which studied the effects of sulfur dioxide on wheat, barley, and alfalfa. EPA obtained seeds from the Scobey area, grew them at Corvallis, and subjected them to various concentrations of sulfur dioxide. The results of this study are included in the effects section of this report.

Very little study has been conducted on the potential for human health effects from pollution from the Canadian plants.

Another type of analysis of the potential for air pollution problems from the generators is "diffusion modeling", a computer aided process which attempts to predict what levels of pollution should result from given emission rates from a given source. Such modeling has been done by Canada (Portelli), EPA (Henderson), and the Air Quality Bureau (Gelhaus). The

modeling has been modified for greater accuracy throughout the negotiation and analysis period. As predictions changed on the expected amount of sulfur dioxide to be generated, upper air meteorology, and power plant design, so did the modeling results. The entire modeling analysis has been used only as a negotiating instrument thus far.

Since 1976 the Canadian government, EPA, and Air Quality Bureau personnel have used a variety of diffusion models to predict the pollution concentrations likely to result from the proposed power plants. Various changes in plant emission data and additional meteorological data have changed the various modeling studies. The more recent modeling performed on the Poplar River plants has been done by EPA (Henderson) and Canada (Portelli). EPA has used two models to predict the concentrations of pollutants from the plants.

One of the models was suited for calculating 24-hour and annual concentrations of pollutants, and the other was used to predict 1-hour concentrations. These predicted 1-hour concentrations were eventually converted mathematically to 24-hour concentrations. Both models assumed the terrain around the source was flat.

Canada has modeled the expected Poplar River emissions with an equation similar to those used by the EPA. Canada did not model the annual case but only modeled the 1-hour concentrations. Uncertainties over the actual emission rates for the various pollutants and meteorological conditions of the area caused the greatest difference between the Canadian and EPA results and remain the greatest uncertainties as to the predicting of pollution concentrations to be expected.

Both Canada and EPA predict Montana pollution concentrations caused by 600 Mw of generating capacity at Poplar River would not violate state or

federal ambient air quality standards. However, Canadian modeling indicates the federal Class II prevention of significant deterioration increment would be violated. Table III summarizes the latest results of modeling performed by EPA and Canada.

TABLE II

DIFFUSION MODELING RESULTS OF THE
POPLAR RIVER POWER PLANTS FOR
SULFUR DIOXIDE
(Values in micrograms per cubic meter)

	EPA+	Canada*
300 Mw		
1-hour	122	220
24-hour	27	97
600 Mw		
1-hour	-	293
24-hour	-	129

+EPA used 8% sulfur retention and 0.83% sulfur content.
*Canada used 0% sulfur retention and 0.86% sulfur content.

The Air Quality Bureau has been collecting meteorological data at the Scobey Border Station since March 1977. This data is needed for modeling of the power plants. Upper air soundings are taken twice a day, three days a week. The use of hourly measurements is recommended instead of time averaging coefficients obtained from less frequent readings. However, hourly stability data was not available in 1977, so the time averaging coefficient derived in the Helena Valley study was used in previous work.

It is recommended that the Poplar River plants (units 1 and 2) be remodeled with as much detail as possible. An entire year of meteorological data from the Scobey area should be used to determine the highest concentrations to be expected and the frequency and duration of various pollution

levels. The modeling effort also should consider the nearby Fort Peck Indian Reservation, which is being studied for possible Class I PSD redesignation. Previous modeling done by the state, EPA, and Canada have only looked at the typical meteorological classes or at a few actual cases. Special analyses should also be done to determine the extent of inversion penetration, plume trapping, and fumigation. Consideration should be given to the time of year when crops are most susceptible to pollution injury.

TABLE III

POPLAR RIVER POWER PLANTS
(Units 1 and 2)

EMISSION PARAMETERS

Stack Height (m)	Gas Exit Temperature (k)	Gas Exit Velocity (m/sec)	Stack Diameter (m)
121.9	425.2	24.2	7.1

TABLE IV

POPLAR RIVER POWER PLANTS
(Units 1 and 2)

EMISSION RATES (g/sec)

S Retention	Sulfur Dioxide	Particulates (99.5% Control)
10%	1386	56.7
20%	1232	
30%	1078	

IV. EFFECTS

Vegetation Effects

Corvallis Study

During 1977 researchers from the Terrestrial Ecology Branch of EPA's Corvallis Environmental Research Laboratory (CERL) attempted to study the potential effects of sulfur dioxide on the plants of the Poplar River area. The study was conducted in controlled field exposure chambers at CERL's Farm Field Site near Corvallis, Oregon. Crops and natural grasses evaluated in the study were grown from seeds and cuttings supplied from the area near the proposed facilities by Montana officials. Soil in the test plots was treated with lime to simulate soil conditions typical of Northeast Montana. The crop species studied included spring wheat, Durum wheat, barley, and alfalfa. Native grasses tested were needle and thread grass, crested wheatgrass, western wheatgrass, blue grama grass, and Russian wildrye.

The CERL study concluded that:

(a) Exposures of sulfur dioxide for approximately three hours per week at concentrations up to 120 pphm had no effect on the growth of the grain and grass varieties tested.
(b) Prolonged low-level sulfur dioxide exposures appeared to be more of a threat to crop yields than short episodes of high exposures.

The vegetation committee of the Poplar River Panel reviewed the CERL study and other work previously done of the effect of sulfur dioxide on vegetation.

The vegetation committee was unanimous in its opinion that the recent studies by CERL did not adequately determine how low doses of sulfur dioxide affect these plants.

The committee concluded:

(a) There is reason to believe that pollution doses similar in magnitude to those in the CERL study have a strong potential to damage crops.
(b) Sulfur dioxide injury to wheat, barley and alfalfa is correlated with the dosage, with the higher doses causing greater injury. The relationship does not appear to be constant over a range of dosages, and it is uncertain how a given level of injury relates to economic loss in various crops. In the case of alfalfa, pollution injury is equated with crop loss, because the usable part of the plant is damaged.
(c) Exposure to sulfur dioxide stressed test plants and caused a variety of responses. It is apparent that plant energy was diverted from normal plant growth and yield toward coping with the irritant gas. Even low sulfur dioxide concentrations appear to reduce yields. The timing of pollution episodes during various phases of plant growth is important.
(d) The magnitude of yield losses are difficult to ascertain in view of the few plants tested, lack of replication, and poorly controlled dosage.
(e) If the CERL test results simulate conditions that would result from the Poplar River facilities, due caution should be used when considering how much sulfur dioxide emission should be allowed.

It is unfortunate that more information revelant to the Poplar River situation could not be derived from the CERL experiments. The vegetation committee recommended that the experiments should be repeated with better experimental design.

A simple calculation was made by the committee to determine potential economic losses of U. S. agriculture from sulfur dioxide pollution that would be emitted from the proposed coal-fired power plant in Canada.

The model made several assumptions based on the apparent design characteristics.

(a) Sulfur dioxide emissions from the 300 megawatt plant will be 64.39 tons per day for 35 years.
(b) The emissions will be carried into Montana 46 percent of the time.
(c) Sixty percent of the sulfur emitted will be deposited within 40 kilometers of the stack.

(d) Because the coal-fired power plant is located approximately 5 miles (8 kilometers) north of the international border, it is assumed that 10 percent of the pollutants will be deposited on the Canadian side by transboundary winds from the north.
(e) The forty percent of pollutants moving beyond the 40 km radius may cause acidification of precipitation at greater distance, with resultant effects.
(f) It was assumed that the sulfur pollutants would be equally distributed over all United States land within the 40 km circle.
(g) Under this assumption, sulfur pollutants in all forms (SO_2, SO_3, SO_4) would fall out at a rate twice the metabolic requirements of plants for sulfur, resulting in a 1 to 2 percent crop yield loss. Crops requiring low amounts of sulfur are assumed to require approximately 5.5 lbs per acre per year. High sulfur requiring crops were assumed to need approximately 60 lbs per acre per year.
(h) It was assumed that crop/rangeland ratio in the U. S. impact zone were as follows:

Cropland	59.5%
Dry Pasture and Range	39.2%

(i) Crop values during the 35 year life of the generating facilities were assumed to be equal to crop values for 1973.

The proposed 300 Mw power plant would emit an average of approximately 64.39 tons per day of sulfur dioxide. Under uniform wind direction conditions and using a worst case deposition rate, it is estimated that 60 percent of the sulfur pollution emitted during the estimated 35-year life of the plant or 493,548.6 tons would be deposited within 40 km of the source (both sides of the border). If the deposition was equally distributed, approximately 22.7 pounds per year of sulfur pollutants would precipitate onto each acre of the land within 40 km of the source. This is more than four times the sulfur required as a nutrient by plants with low sulfur demand, such as native range grasses, trees, wheat, barley and alfalfa. The addition of the amount of sulfur expected to be deposited on the land within 40 km of the source probably would result in stress and crop loss in plants with low sulfur requirements.

Using the equation:

(% transboundary winds (N, NNE, NNW) x (total SO_2 tonnage) x (estimated % deposition in U.S.) divided by (acreage w/in plume influence) divided by (plant lifetime) x (2000 lbs) = pounds per acre per year

(.174) x (493,548.6) x (.50) divided by 35 x 2000 = 102 lb/acre/year

The 102 lb/acre/year is weighted as sulfur dioxide.

It is obvious that the location of the power plant relative to the border is crucial to the pollutant load deposited in the United States. There is clearly more than enough sulfur pollutant likely to be deposited on the U.S. side to saturate plant tissue with sulfur. This is primarily because of the efficiency of plants in absorbing atmospheric sulfur pollutants. The primary molecular forms of the power plant sulfur pollutants are sulfur dioxide and sulfuric acid, the action of which at the estimated sedimentation rates would be sufficient to elicit 1-2% crop losses.

Nyborg's et al. estimated effects from acid rain (acid rain symposium proceedings) applied at a rate of 50 kilograms per hectare per year are useable in estimating likely impacts from acid rain in the Poplar River case. Nyborg et al. estimated that 50 kg/ha/yr was capable of reducing soil pH 1 unit in 10-20 years.

102 lb/acre/year = 112 kilograms/ha/yr

Weighted as elemental sulfur, 102 lb/acre/year of SO_2 is equivalent to 50 kg/ha; somewhat greater than Nyborg's estimated critical level for inducement of rapid soil acidification.

Sulfur sedimentation at these rates would soon saturate the ability of plants with low sulfur requirements to accumulate, transport, or excrete enough sulfur to keep pace with the deposition from the air. A yield loss

estimate between 1 and 2 percent probably would be lower than that actually occurring.

High sulfur requiring plants would tend to accumulate the excess sulfur and metabolize it normally, unless sulfur dioxide concentrations at or above 0.05 ppm occurred. A 1-2% loss could be predicted for some high sulfur requiring plants. In the areas of heaviest impact, a conservative estimate of crop loss of more than 2% could be conservatively estimated.

Of the pollution carried by the wind into Montana, 17.4 percent would be borne by winds from the 45 degree span ranging from NNW to NNE. Winds blowing more obliquely from east or west would have less potential to carry pollution into Montana. If it is assumed that the pollution plume has the normal 5 km width at 8 km from the source and 18 km width at 30 km, then 24,000 acres of Montana land are in the area SSW to SSE of the source. Plants in this area could be subjected to stress from sulfur pollution. The calculation of the acreage allows for plume overlap and meandering along centerlines.

A 40 kilometer radius circle around the proposed coal-fired plant extends eight miles south of Scobey, Montana, east into Sheridan County and to within five miles of Valley County to the west (see map).

The primary use of the land is wheat and alfalfa croplands with about 25% predominantly grasslands used for livestock grazing. Five U.S. towns are within the 40 kilometer area of plume influence:

(1) Scobey
(2) Flaxville
(3) Four Buttes
(4) Whitetail
(5) Madoc

The grasslands are primarily located along the tributaries of the Poplar River where wind currents probably would flow. Grassland conditions in the area of influence are rated on the average as approximately 60% good to excellent. The worst range is located nearest to the power plant at R 47E, T 37N, with range conditions good to excellent on 20-90% of the rangeland. Rangelands presently being stressed by other factors including erosion or herd pressures could be expected to be the most sensitive to pollution from the power plant.

Range acreages in townships average from less than 3,000 acres per township to 14,000 acres, with most townships having 3,000-8,000 acres. Wheat, barley, oats, hay, and range plants are the principal crops excluding livestock. These crops are generally classified as being sensitive or hypersensitive to SO_2. In 1973 farms in the district ranked 21st among all Montana counties in average cash receipts per farm. Cash receipts for 1973 were 24.3 million dollars. Livestock and livestock products accounted for 16% of total cash receipts.

The sum of Daniels County cropland acreage = 543,166.
The value of the cropland products in 1973 = twenty million dollars.

The average value per acre in 1973 was, therefore, $37.00.

The sum of Daniels County range and pastureland acreage = 357,446.
The value of livestock from that acreage was 3.888 million dollars.

The average value per acre in 1973 was approximately $10.88.

The 40 km radius circle contains 502,654.8 hectares.
The distance from the power plant to the border is approximately 8 km.
Southern half of circle on Canadian side is approximately 640 km^2.

Therefore: $\frac{1}{2} \times 5026.5$ minus 640 = 1873 km^2 in U.S. impact zone.
1873 km^2 = 452,704 acres.

With the previously stated crop ratios for the impact zone of 59.5% cropland and 39.2% range and dry pasture, the above stated value per acre per crop type and a 1% loss to these crops would mean:

Annual cropland losses would be $99,662
Annual range and dry pasture losses will be $17,746

Sum of annual crop losses in Daniels County, Montana due to power plant - $117,408

Sum of crop losses over 35 year lifetime of power plant = $4,109,280 (assuming a constant loss each year)

Using a standard economic loss this would be $1,643,712.

This loss estimate probably includes direct effects on plants during the growing season, and indirect effects from accumulation of acid in snow and soil. It doesn't include the effects of pollutants other than sulfur dioxide and its derivatives. Losses probably would double if generating capacity were increased from 300 Mw to 600 Mw. Plant losses would more than double near the source. However, even at double the loss estimates, cost of the direct plant losses is far less than the cost of a sulfur dioxide scrubber for the power plant. Therefore, the power company has little incentive to install a scrubber system other than a good neighbor policy.

This estimate does not consider decreases in crop productivity from fertility loss of the soil caused by gradual acidification from sulfur pollution. An estimated 1% loss to agriculture in Daniels County should be considered the lowest likely figure. Losses will not occur evenly over the impact area. Fumigation episodes during the 35 year period can be expected to cause more than 1% acute damage in some areas. Sulfur dioxide carried in the air can be expected to create acid precipitation for substantial distances downwind. Pollutant effects occurring beyond 40 km from the sources are not considered herein. Areas predominately downwind from the power plant will be stressed more than those not influenced by the wind.

Acreage devoted to minimum and no-tillage small grain culture will be particularly vulnerable to acidification in the upper soil. Native rangelands will be selectively stressed, with species diversity expected to be reduced under continual grazing pressure and chronic SO_2 exposure.

Even if agriculture losses are a magnitude less than projected (one tenth of one percent instead of one percent per year), the extent of loss is unacceptable to a maximization of the prime agricultural industry in Daniels County.

Health Effects

The accurate prediction of possible adverse health effects on the human population of Daniels County is directly dependent upon the most accurate predictions of the pollutant levels to be expected from the Canadian power plants. Both Canada and the EPA predict concentrations of pollutants (particulates and sulfur dioxide) due to the emissions of the two Poplar River plants to be below the state or federal ambient air quality standards in Daniels County, Montana. According to the Canadian model employed, the federal Class II PSD standards would be violated with the second plant.

The predicted levels of TSP or of sulfur dioxide are well below levels clearly associated with morbidity in the general population, and probably with morbidity in persons with chronic lung disease. The levels predicted do not at all correspond with the levels associated with excess mortality in urban areas (e.g., Pittsburgh, London).

In general, air pollution with particulates and sulfur dioxide have been poorly correlated with definite morbidity and mortality, except in the presence of very high levels (e.g., over 700-800 ug/cm). The persons most

clearly affected at those levels are those with chronic lung diseases, especially obstructive lung diseases; the diseases such as cancer of the respiratory tract or chronic heart failure are, at most, only vaguely associated casually with ambient air pollution.

Cancer mortality data compiled by the National Cancer Institute (NIH) by county for the U.S. from 1950 through 1969 indicates a risk of white male residents in Daniels County dying of cancer of the trachea, bronchus or lung, that is significantly less than the total U.S. (age-adjusted). The comparable rate for white females is not significantly different from the U.S.

Mortality data compiled by the Air Quality Bureau, with the assistance of Preventive Health Services Bureau and Records and Statistics Bureau, for the years 1969-1973 indicate no significant difference from the Montana population for any respiratory disease in Daniels County residents (Tables 6 through 9). In Daniels, Sheridan, and Roosevelt Counties combined, there is a tendency for increases in mortality from various circulatory diseases, notably cerebrovascular disease; this increase is modest and clustered in those persons over 65 years of age (Table 5).

The Montana mortality data, as compiled, are associated with, or imply, no recognizable etiologic factor; the possible influences of cigarette smoking, alcohol intake, heredity, age, medical care, or air pollutants are not analyzed, and no etiologic assumptions can be made, suggested, or implied from these data.

Results of previous comparisons of death rates have postulated that the "health" of Daniels, Sheridan, and Roosevelt County residents has been "stressed by some unknown factor." With negligible air pollution, small and aged populations, and no significant increases in mortality from obstructive

lung disease, it is difficult, if not impossible, to defend such a concept. Just because old people die, does not mean that the populace has been stressed.

In conclusion, there would be no adverse health effects on the human population of Daniels County attributable to the Canadian plant up to the 600 Mw operation, based on the predictions supplied. If the emissions increase substantially, the possibility of potential adverse health effects will need to be re-evaluated.

Visibility Effects

Visibility impairment due to the operation of the power plants remains unassessed. Particulate emissions directly from the power plant and sulfates and nitrates formed from gaseous emissions of the power plant all will reduce visibility in the area. Background measurements of present visibility related parameters are being made at the U.S.-Canada border. Measurements are being made using a diffuse radiation system, a multichannel sun photometer, and an integrating nephelometer. Related measurements are being made of fine particulate concentrations, sulfate and nitrate concentrations, and meteorological parameters. However, all of these measurements are designed to detect differences in visibility related parameters after the startup of the power plants.

A request was made through the Los Alamos Scientific Laboratory to have several types of visibility models run to predict possible visibility reduction. The Los Alamos Lab has tentatively agreed to do the work under a related contract. Background information and supplementary has been supplied to Los Alamos by the Air Quality Bureau. As of the publication date of this report no information relative to the models has been received. Should this information be received by July, 1979, it will be included in the background visibility assessment report due to be published by the Air Quality Bureau in July, 1979.

(TABLE V)

SURVEILLANCE OF MORTALITY IN DANIELS COUNTY

YEAR	TOTAL POPULATION			TOTAL DEATHS			HEART DISEASE DEATHS			CANCER DEATHS			COPD DEATHS		
	MONT.	DANIELS	RATIO	MONT.	DANIELS	RATIO	MONT.	DANIELS	RATIO	MONT.	DANIELS	RATIO	MONT.	DANIELS	RATIO
1968	693,000	3,300	4.8	6,534	39	6.0	188	4	21.3	2,223	12	5.4	1,080	7	6.5
1969	694,000	3,100	4.5	6,694	45	6.7	145	0	--	2,297	17	7.4	1,041	7	6.7
1970	694,400	3,100	4.5	6,597	49	7.4	173	0	--	2,229	23	10.3	1,059	7	6.6
1971	710,000	3,100	4.5	6,860	58	8.5	148	0	--	2,339	20	8.6	1,050	8	7.6
1972	719,000	3,000	4.2	6,896	43	6.2	155	0	--	2,294	17	7.4	1,122	5	4.5
1973	721,000	3,100	4.3	6,870	33	4.8	170	0	--	2,300	10	4.3	1,061	6	5.7
1974	735,000	3,200	4.4	6,552	37	5.6	119	0	--	2,202	15	6.8	1,130	6	5.3
1975	748,000	3,000	4.0	6,539	24	3.7	147	0	--	2,178	9	4.1	1,105	4	3.6
1976	753,000	3,200	4.2	6,733	36	5.3	120	0	--	2,178	14	6.4	1,191	8	6.7
1977	761,000	3,100	4.1	6,397	27	4.2	117	1	8.5	2,149	11	5.1	1,184	6	5.1
5 YEAR MEDIAN															
I 1968-1972	694,400	3,100	4.5	6,694	45	6.7	155	0	--	2,294	17	7.4	1,059	7	6.6
II 1973-1977	748,000	3,100	4.1	6,552	33	4.8	120	0	--	2,178	11	5.1	1,130	6	5.3
TOTAL 1968-1977	728,000	3,100	4.35	6,646	38	5.8	146	0	--	2,231	14.5	6.6	1,093	6.5	6.1

TABLE 6

SHERIDAN COUNTY DEATH RATES

	Rate*	Number**	Level of Significance	State Rate	Comparison to State Rate
Circulatory Diseases					
All Ages	629.3	183	++	479.4	31% higher
Male	756.8	112	++	556.0	36% higher
Female	479.2	71		402.8	19% higher
Ages 40-64	274.5	24		383.2	
Male	417.3	19		555.9	
Ages 65 & Over	4589.0	158	+	3744.6	23% higher
Male	5529.1	93		4397.5	26% higher
Female	3695.3	65		3190.4	16% higher
CerebroVascular Disease					
All Ages	79.1	23		103.8	
Male	73.4	11		101.8	
Female	84.0	12		105.9	
Ages 65 & Over	609.9	21		895.5	
Male	594.5	10		939.4	
Female	625.4	11		858.8	
Cancer of Respiratory System					
All Ages	58.5	17	+	30.1	94% higher
Male	101.8*	16	+	49.4	106% higher
Ages 65 & Over	319.5	11		151.1	111% higher
Male	654.0	11	+	275.8	137% higher
Respiratory Disease					
All Ages	72.2	21		65.4	10% higher
Male	101.4	15		88.4	15% higher
Ages 65 & Over	319.5	11		457.4	30% lower
Asthma, Emphysema & Bronchitis					
All Ages	37.8	11		22.4	69% higher
Male	74.3	11		35.7	108% higher

*Deaths per 100,000 population.
**Numbers taken from 1969-1973 death certificates.

+Significant at 1% level: Chi-Square 6.63-10.82.
++Significant at 0.1% level: Chi-Square greater or equal to 10.83.

TABLE 7

ROOSEVELT COUNTY DEATH RATES

	Rate*	Number**	Level of Significance	State Rate	Comparison to State Rate
Circulatory Disease					
All Ages	617.6	324	++	479.4	29% higher
Male	777.5	203	++	556.0	40% higher
Female	459.1	121		402.8	14% higher
Ages 40-64	581.8	76	++	383.2	52% higher
Male	878.0	58	++	555.9	58% higher
Female	278.8	18		207.7	34% higher
Ages 65 & Over	4780.6	243	++	3744.6	28% higher
Male	5843.9	143	++	4397.5	33% higher
Female	3797.9	100		3190.4	19% higher
CerebroVascular Disease					
All Ages	114.4	60		103.8	
Male	103.4	27		101.8	
Female	125.2	33		105.9	
Ages 65 & Over	1042.7	53		895.5	
Male	899.1	22		939.4	
Female	1177.4	31		858.4	37% higher
Cancer of Respiratory System					
All Ages	21.0	11		30.1	
Male	38.3	10		49.4	
Respiratory Disease					
All Ages	83.9	44		65.4	28% higher
Male	84.3	22		88.4	
Female	83.5	22	+	42.4	97% higher
Ages 65 & Over	570.5	29		457.4	25% higher
Male	653.9	16		689.4	
Female	493.7	13		259.8	90% higher
Pneumonia					
All Ages	70.5	37	++	30.5	131% higher
Male	65.1	17		36.1	80% higher
Female	75.9	20	++	24.9	205% higher
Ages 65 & Over	511.5	26	++	224.2	128% higher
Male	572.1	14	+	285.0	101% higher
Female	455.8	12	++	172.5	164% higher

*Deaths per 100,000 population.
**Numbers taken from 1969-1973 death certificates.

+Significant at 1% level: Chi-Square 6.63-10.82.
++Significant at 0.1% level: Chi-Square greater than or equal to 10.83.

TABLE 8

DANIELS COUNTY DEATH RATES

	Rate*	Number**	Level of Significance	State Rate	Comparison to State Rate
Circulatory Diseases					
All Ages	865.5	134	++	479.4	81% higher
Male	900.1	78	++	556.0	62% higher
Female	736.4	56	++	402.8	83% higher
Ages 40-64	485.9	22		383.2	27% higher
Male	774.5	18		555.9	39% higher
Ages 65 & Over	4895.1	112	+	3744.6	31% higher
Male	5366.7	60		4397.5	22% higher
Female	4452.1	52		3190.4	40% higher
CerebroVascular Disease					
All Ages	108.8	28	+	103.8	5% higher
Male	190.4	15		101.8	87% higher
Female	170.9	13		105.9	61% higher
Ages 65 & Over	1005.2	23		895.5	12% higher
Male	1070.3	12		939.4	14% higher
Female	941.8	11		858.8	10% higher

*Deaths per 100,000 population.
**Numbers taken from 1969-1973 death certificates.

+Significant at 1% level: Chi-Square 6.63-10.82.
++Significant at 0.1% level: Chi-Square greater than or equal to 10.83.

TABLE 9

PERCENTAGE OF PERSONS OVER 45 YEARS OLD BY COUNTY

County	Percent	County	Percent
1. Carbon	44.3	29. Custer	33.3
2. Sweet Grass	42.7	30. Garfield	33.0
3. Musselshell	42.7	31. Powell	32.4
4. Prairie	41.1	32. Richland	32.0
5. Stillwater	39.6	33. Treasure	31.9
6. Park	39.4	34. McCone	31.7
7. Madison	39.3	35. Blaine	31.6
8. Wheatland	39.3	36. Pondera	31.3
9. Golden Valley	38.6	37. Beaverhead	31.2
10. Daniels	38.4	38. Lewis & Clark	30.9
11. Judith Basin	38.4	39. Flathead	30.7
12. Deer Lodge	38.2	40. Liberty	29.3
13. Carter	37.4	41. Rosebud	29.2
14. Granite	37.4	42. Roosevelt	29.1
15. Ravalli	37.0	43. Mineral	28.9
16. Teton	37.0	44. Jefferson	28.4
17. Meagher	36.2	45. Fallon	28.1
18. Fergus	36.1	46. Valley	28.1
19. Petroleum	36.1	47. Yellowstone	27.8
20. Sanders	35.8	48. Dawson	27.4
21. Sheridan	35.7	49. Hill	27.3
22. Broadwater	35.5	50. Glacier	26.3
23. Silver Bow	35.5	51. Big Horn	25.4
24. Lake	35.4	52. Cascade	25.3
25. Wibaux	34.9	53. Missoula	24.8
26. Choteau	34.8	54. Powder River	24.7
27. Phillips	34.3	55. Gallatin	24.3
28. Toole	33.8	56. Lincoln	24.3

State percentage 30.2.

Data taken from 1970 census.

V. RECOMMENDATIONS

The panel has reviewed the probable effects and the issues remaining unanswered on the Poplar River air quality related to the proposed power plants. Based on this review the panel believes there are certain areas that the Canadians must address prior to the startup of the power plants. These include:

(1) It is still the policy of Montana to require all power plants constructed in the state to install the Best Available Control Technology (BACT) for sulfur dioxide. BACT has been demonstrated by the proposed power plants at Colstrip to be 95% control. As part of a good neighbor policy Montana will not allow facilities to pollute Canada or other states but will require BACT. Canada should return the gesture and not allow the Poplar River plants to unnecessarily pollute Montana.

(2) In order to determine the effects of the first Poplar River power plant and to predict the potential effects of additional units the power plant must be installed with:

(a) continuous in-stack emission monitoring meeting EPA equivalency requirements for sulfur dioxide, nitrogen dioxide, opacity, and carbon monoxide;
(b) continuous integrated coal sampling on the coal conveyor; and
(c) a more in depth field sampling and analysis of coal to determin the horizontal and vertical distribution of sulfur and various trace elements.

(3) Montana has contributed a great deal of resources to assessing the present air quality related parameters. It is only fair that the Canadians contribute one-half of the expense to the future studies that the Air Quality Bureau feels should be addressed. These studies include:

(a) the operation of three continuous ambient sulfur dioxide stations for a period of two years following the startup of the last unit to be built in the foreseeable future (one of which is presently operating at the Scobey Border Station; the second and third would be installed on the Fort Peck Indian Reservation and at point east of the present station);
(b) a detailed modeling of the projected visibility impairment anticipated from the first and additional power plants;

(c) a sulfate formation characterization study including sulfates present in the background and sulfates formed from sulfur dioxide and the available cations present;
(d) a study of the baseline levels of trace elements in the wildlife of the area;
(e) a continuation of the vegetation and soil sampling and analyses after operation of the first unit; and
(f) an extension to the Poplar River area of a health effects study being conducted in other parts of Montana. Testing or analysis includes mortality statistics and pulmonary function measurements.

(4) As a last step for the residents of northeastern Montana, northwestern North Dakota, and south Saskatchewan, the Saskatchewan Power Corporation should set aside a $10 million bond to defray the cost of the effects of the air pollution on these residents or their property. This should be done to prevent the residents from being required to sue the power corporation in a Canadian court.

The panel believes that Canada has not taken enough steps to prevent damage to Montana due to air pollution emissions from the Poplar River power plants. The areas of additional work addressed in this paper are very important to Montana's environment and economy.